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A STUDY OF TASK LOADING USING A FOUR-MAN CREW ON A KC-135 AIRCR--ETC(U)
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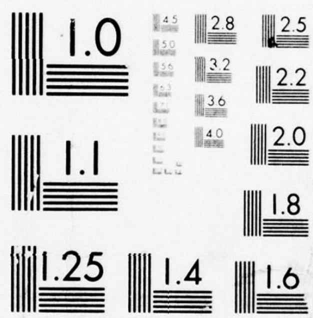

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A STUDY OF TASK LOADING USING A FOUR-MAN CREW ON A KC-135 AIRCRAFT (GIANT BOOM)

Crew Station Escape and Human Factors Branch
Crew Equipment and Human Factors Division

APRIL 1977

Technical Report ASD-TR-76-33
Final Report for Period July 1976 to October 1976

Approved for public release; distribution unlimited

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AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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At the request of Strategic Air Command (SAC), human factors engineers and engineering psychologists participated in this KC-135 crew composition and task load analysis entitled GIANT BOOM. GIANT BOOM, a follow-on study to SAC's earlier GIANT CHANGE, determined the feasibility of a four-man KC-135 crew consisting of two pilots, a boom operator, and an enlisted Flight Systems Operator. This crew complement, with inertial navigation systems and radars for the pilots and Flight Systems Operators, demonstrated significantly reduced task loads on both pilots from those observed in GIANT CHANGE.

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FOREWORD

This technical report was prepared by the Human Factors Group of the Crew Equipment and Human Factors Division, Directorate of Equipment Engineering, Deputy for Engineering, Aeronautical Systems Division, Wright-Patterson AFB, Ohio under Job Order Number ASDD0008. Data was collected on overland, overwater, and polar flight missions with the 509 Air Refueling Squadron, Pease AFB, New Hampshire between July 1976 and October 1976. Data was analyzed and an initial version of this technical report was forwarded to Strategic Air Command (SAC) for inclusion as an addendum to SAC's GIANT BOOM FINAL REPORT.

The principal investigators were Mr. Richard Geiselhart, Captain Richard I. Koeteeuw, and Mr. Richard J. Schiffler of Aeronautical Systems Division. The authors would like to thank the crews, staff, and maintenance personnel of the 509th Air Refueling Squadron (AREFS) and the 509th Bombardment Wing who participated in and supported this study. Because of their outstanding perseverance and many significant contributions to this test program in addition to performing regular squadron duties concurrently, special thanks are extended to Major John Tucker, Lt Chris Cross, Lt Denis Cesarz, SMS Haven Moore, MSgt Robert Whittier, Capt Michael Pearson, Capt Michael Miller, Capt Robert Gustafson and Lt Charles Lovejoy.

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SECTION I

INTRODUCTION

Earlier this year (1976), a study was performed jointly by the Strategic Air Command (SAC) and the Crew, Escape and Human Factors Branch, Aeronautical Systems Division (ASD/ENECC) on the feasibility of using a three-man crew on a KC-135 aircraft (GIANT CHANGE). This study indicated that omitting the navigator and giving the navigation function to the copilot resulted in excessively high workloads on the copilot that jeopardized the mission and, in some cases, constituted a safety hazard. As a result, further testing was directed by the Commander-In-Chief, Strategic Air Command (CINCSAC). The purpose of this follow-on program, designated GIANT BOOM, was to determine if the addition of a fourth man to the crew would alleviate the shortcomings of the three-man crew. This fourth man was an additional boom operator, designated a Flight Systems Operator (FSO), who was given training in the fundamentals of navigation, radar scope interpretation, operation of the inertial navigation system (INS), and rendezvous (Rz) procedures. The function of the enlisted FSO was to provide assistance to the copilot who still had primary responsibility for the navigation function. The FSO's primary duties were to operate and interpret the radar scope and to relieve the copilot of navigation duties during periods of peak workload. Radar work consisted of monitoring weather and receiver rendezvous, taking navigation fixes, and shooting Airborne Radar Directed Approaches (ARDA). Copilot relief consisted of checking waypoints on the INS and plotting a new course when required for mission change or weather avoidance. In order to investigate and compare the workload reduction on the copilot, missions similar to those on GIANT CHANGE were flown.

SECTION II

METHODOLOGY

The flight test program conducted over a 60-day span consisted of 16 sorties covering a range of refueling operations similar to those encountered in SAC's operational environment. A summary of these types of missions is shown in Table 1.

Prior to the test flights, the FSOs were given a 30-day course at Castle AFB, California on fundamentals of navigation, radar scope operation and interpretation, and the use of the INS.

Table 2 presents age and flying experience averages for the crew members participating in GIANT BOOM. Aircraft commanders (P) and safety observer pilots (O) averaged 28 years of age, 1300 hours in total flying time, and about 900 hours in the KC-135. Copilots (CP) averaged 24.5 years of age, 800 hours in total flying time, and 600 hours in the KC-135. Flight Systems Operators (FSO or F) averaged 40 years of age, 5100 hours in total flying time, and 2800 hours as KC-135 Boom Operators. Ps and CPs averaged 1 1/2 years' experience in their current crew positions, Os averaged just over two years, and FSOs averaged almost 14 years' prior experience as boom operators.

The procedure used in this study was similar to that used in earlier studies where task loading was calculated according to the following formula: $\text{Percentage crew workload} = \frac{\text{time required}}{\text{time available}} \times 100.$

This formula gives the average time unit to accomplish a task. For example, a 77 percent crew workloading would mean that for 77 minutes out of a 100-minute mission segment an operator would be busy accomplishing some required task. The time available is determined by the mission, aircraft performance, operational environment, or some combination thereof. This measures "overt task loading" (i.e., directly observable behavior or task accomplishment).

TABLE I

GIANT BOOM

TYPES OF MISSIONS

1. MITO (MINIMUM INTERVAL TAKEOFF)

2. CELL

3. MISSION CHANGE

4. HIGH LATITUDE

5. CRESTED CAP

TABLE 2

GIANT BOOM CREW EXPERIENCE AVERAGES

CREW POSITION	AGE	TOTAL FLYING HOURS	KC-135 FLYING HOURS	EXPERIENCE PRESENT POSITION	EXPERIENCE PRESENT CREW
AIRCRAFT COMMANDERS	27.5	1300	855	1YR 5MO	1YR 4MO
COPILOTS	24.5	788	588	1YR 5MO	6 MO
FLIGHT SYSTEMS OPERATORS	40	5100	2800	13YR 10MO (AS BOOM OPER)	(NEW POSITION)
OBSERVER PILOTS	28.25	1319	990	2YR 1MO	4 WK

Overt task were timed and recorded in the broad categories of navigation, communications, radar, INS, instrument reading, and miscellaneous activities. INS and radar categories consisted of only those tasks where the FSO was physically observing, tuning, or operating the actual equipment. Activities involving chart, log, or hand/computer calculations were included in the navigation category whether or not they involved information to be used with INS or radar. Other navigation activities were performing checklists and computing estimated times of arrival (ETAs). Communications activities included radio and interphone conversations with crew and receivers, tuning high frequency (HF) radios, obtaining radio frequencies, and authenticating messages. Instrument reading was that activity where the copilot was reading instruments as cross checks for the pilot or when flying the aircraft himself. Miscellaneous tasks were those where actual workloads did not readily fit into other categories.

SECTION III

RESULTS

1. Taskload Data

As in the earlier GIANT CHANGE Program, the data from GIANT BOOM was analyzed across those missions on which representative ranges of task loads were encountered. The data analysis was also limited to the later flights after learning effects stabilized. Figures 1 and 2 show the copilot and FSO workloads, respectively, on a mission change involving an additional refueling. The copilot task load increased from 50 percent on a standard refueling mission (where no problems occur) to 67 percent for the additional refueling. The FSO showed a similar increase in task load--81 percent for the standard mission[1] versus 100 percent for the mission change. This full loading extended over a 20 to 30 minute period during which the FSO authenticated the change, plotted and coordinated route changes, determined and discussed new waypoint coordinates, monitored complete INS reprogramming by the copilot, calculated new ETAs and necessary airspeed adjustments, and began to prepare for radio contact with the new receiver.

The FSO's mission change task load showed an increase in the cockpit communications needed to insure a smooth coordinated change, an increase in the actual manipulation of the INS (carefully checked during copilot reprogramming as well as during fixing), and a very large increase in navigation. This navigation increase was primarily inflight route analysis and replanning, and was added onto the standard navigation workload by dropping the radar workload. GIANT BOOM crews found the best workload distribution during mission changes kept the pilot out of the details of the route change and waypoint insertion

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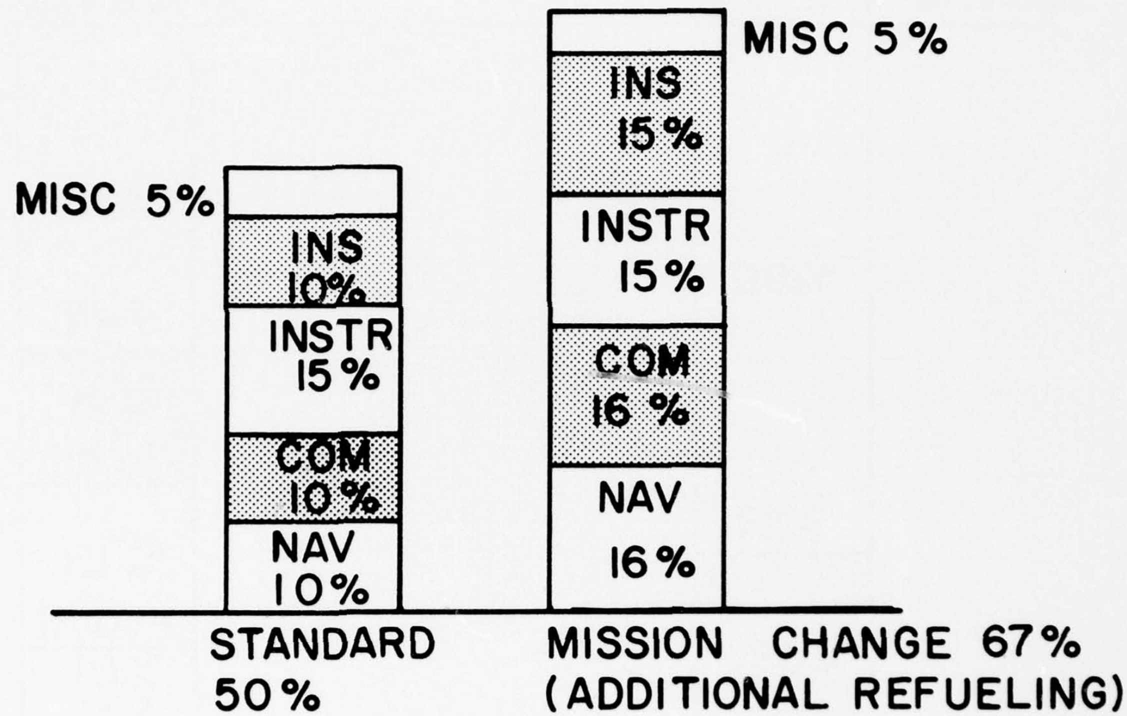
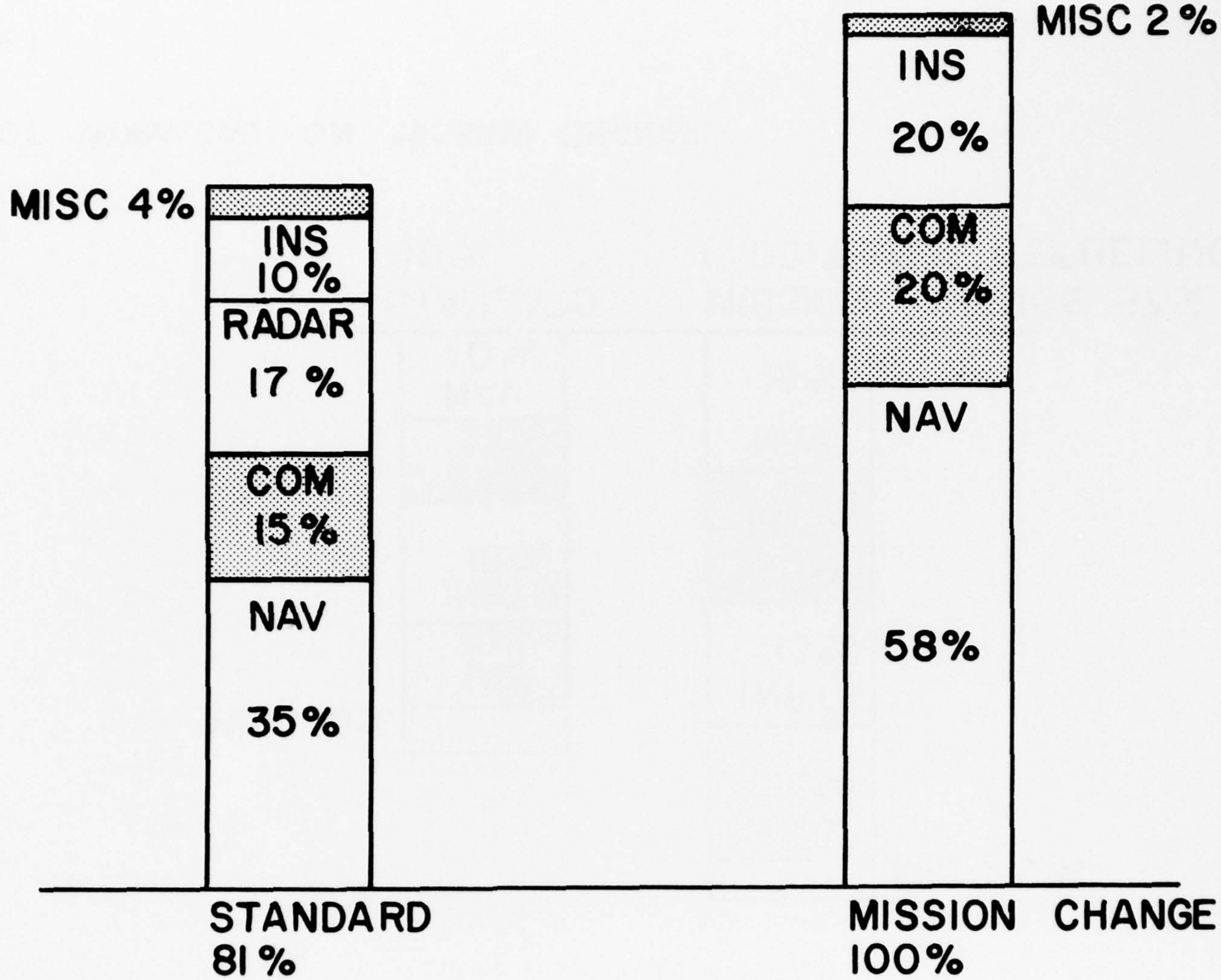
1 The authors feel that the FSO workload figures on the standard mission were somewhat inflated because the FSO, by and large, performed more navigation duties than required (this issue is addressed in detail in the Discussion section).



COPILOT WORKLOAD ON MISSION CHANGE

FIGURE 1



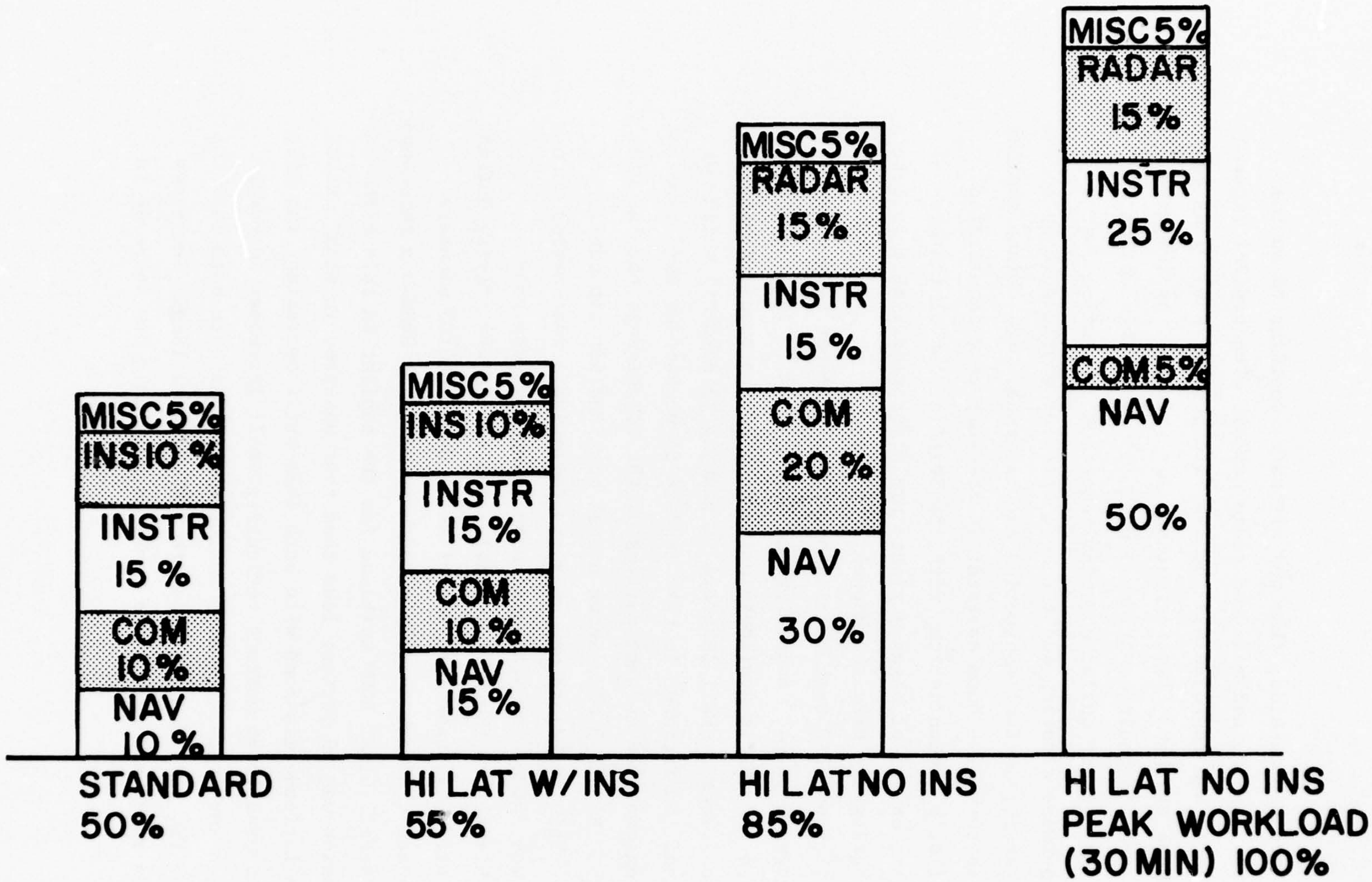
FLIGHT SYSTEMS OPERATOR WORKLOAD ON MISSION CHANGE

FIGURE 2

(i.e., pilot scanned outside, flew the aircraft, coordinated on the strategy of the change, and made the radio calls). The copilot figured the route changes and reprogrammed the INS with the FSO monitoring and confirming those changes. Two suggestions for this busy period were given by the crew in their questionnaires: (1) Since the copilot has his head in the cockpit during waypoint insertion, the pilot must do most of the outside clearing and the boom operator should move up to the jump seat to assist in fuel monitoring and clearing; (2) Since copilot and FSO are so busy, the boom operator in the jump seat should also backup the pilot's communications with Air Traffic Control (on his initial flight, one pilot began a right-turn after receiving a left-turn instruction during the mission change).

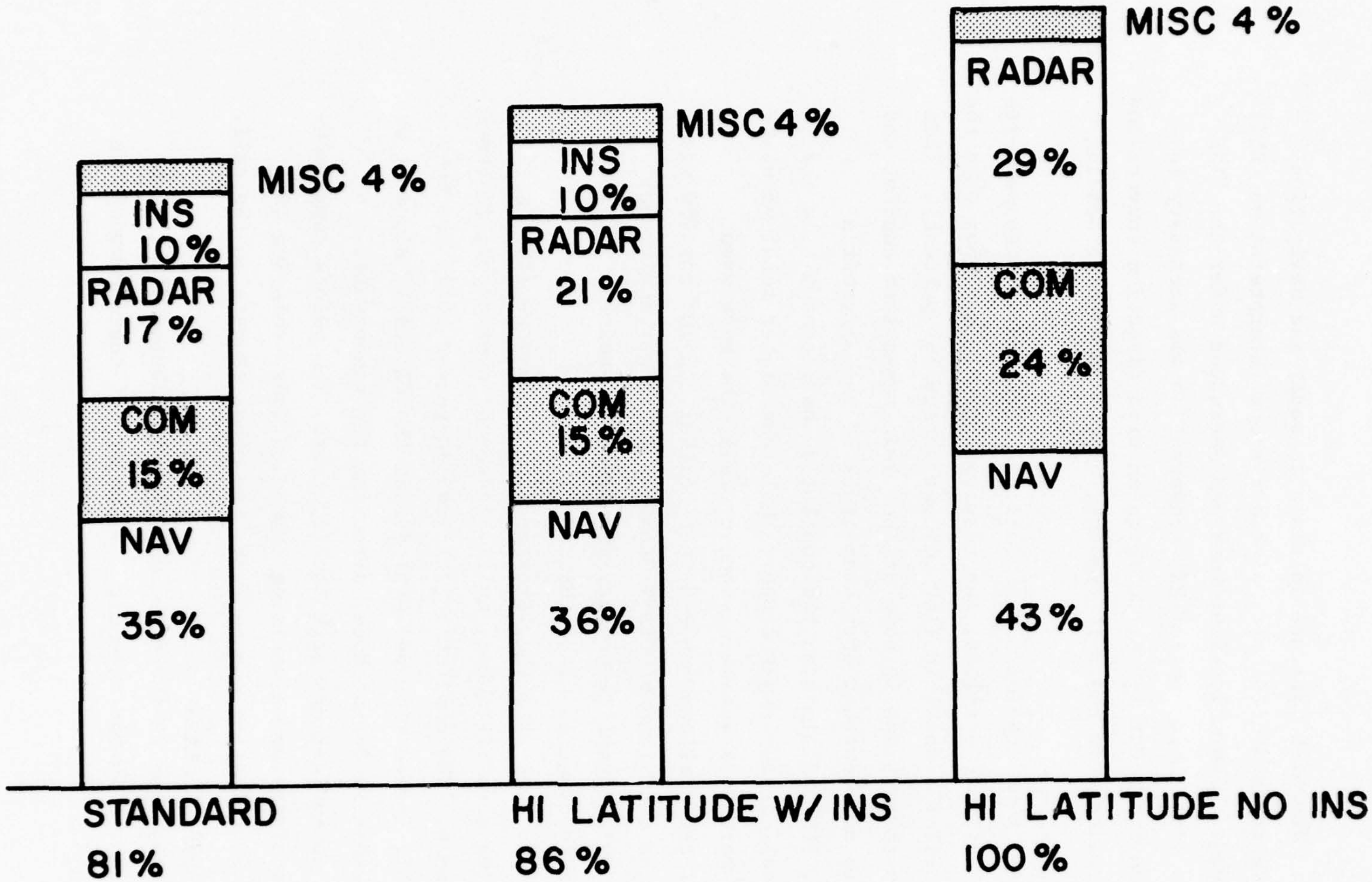
The copilot and FSO task loading on a high latitude flight are shown in Figures 3 and 4. Comparing the copilot's high latitude task load data when the INS is available with those of the standard mission (Figure 3), one sees a small increase in tasking (5 percent) which was not unexpected. An increase in task load to 85 percent on this same mission was encountered on that portion of the flight when the INS was not available. Figure 3 also shows a peak workload for the copilot of 100 percent. This task load was measured following a rest period when the copilot was out of the seat and, upon returning, was busy reorienting himself to the mission while also taking over flying duties from the pilot. This task load was of short duration (30 minutes). These task loads contrast sharply with those of GIANT CHANGE's three-man crew. The overall GIANT BOOM workload for the copilot on this high latitude mission was 60 percent less than that observed in GIANT CHANGE.

On high latitude missions with both INSs still operating, the FSOs workload increased to 86 percent reflecting small increases in radar and navigation workloads. On high latitude missions with both INSs "failed," the FSO workload increased to 100 percent; larger increases were found in radar and navigation tasks as well as a new increase in



COPILOT'S WORKLOAD ON HIGH LATITUDE FLIGHT

FIGURE 3



FLIGHT SYSTEMS OPERATOR WORKLOAD ON HIGH LATITUDE FLIGHT

FIGURE 4

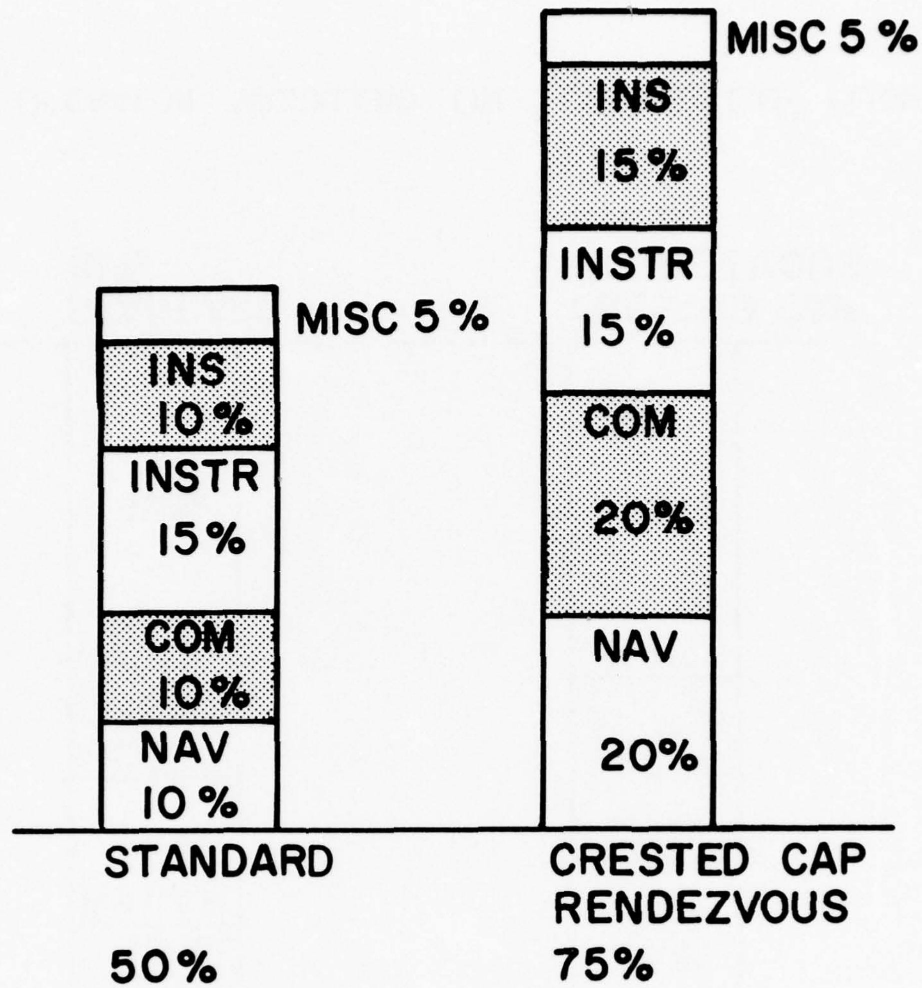
communications. The high latitude increase in radar and navigation was due to the increased difficulty of radar scope interpretation (RSI) in northern Canada. Communications workload increased under the "INS out" conditions since more copilot-FSO conversation was necessary to identify and confirm radar fixes, to agree on Grid direction conversions (autopilot operating from the N-1 Compass), and to coordinate heading changes.

If the GIANT BOOM copilot's high latitude workload is combined with the FSO's high latitude workload, the resultant total is higher than the GIANT CHANGE copilot's workload (140 percent versus 185 percent). This was due largely to overlaps in some of the basic tasks that copilot and FSO both have to do when they both keep track of the aircraft's position; e.g., INS positions on the copilot's chart cannot help the FSO orient himself in the radar scope. While the higher total percentages indicated more work was being done overall, the more even distribution of the workloads showed that neither copilot nor FSO was near the overload condition of GIANT CHANGE. The lower individual workloads and navigational redundancy greatly decreased the fatigue factor that was observed on GIANT CHANGE.

The task load data from the "Crested Cap" rendezvous (RZ), a mission involving a multi-tanker, multi-fighter RZ over water, is shown in Figures 5 and 6. The copilot's task load increased to 75 percent. The FSO was fully loaded (100 percent) during the RZ itself since he was operating the radar in Beacon Mode, directing the rendezvous, and performing the communications with the fighters. The pilots complemented the FSO's activity by maintaining communications, relaying INS positions, and coordinating changes with the other tankers in the cell.

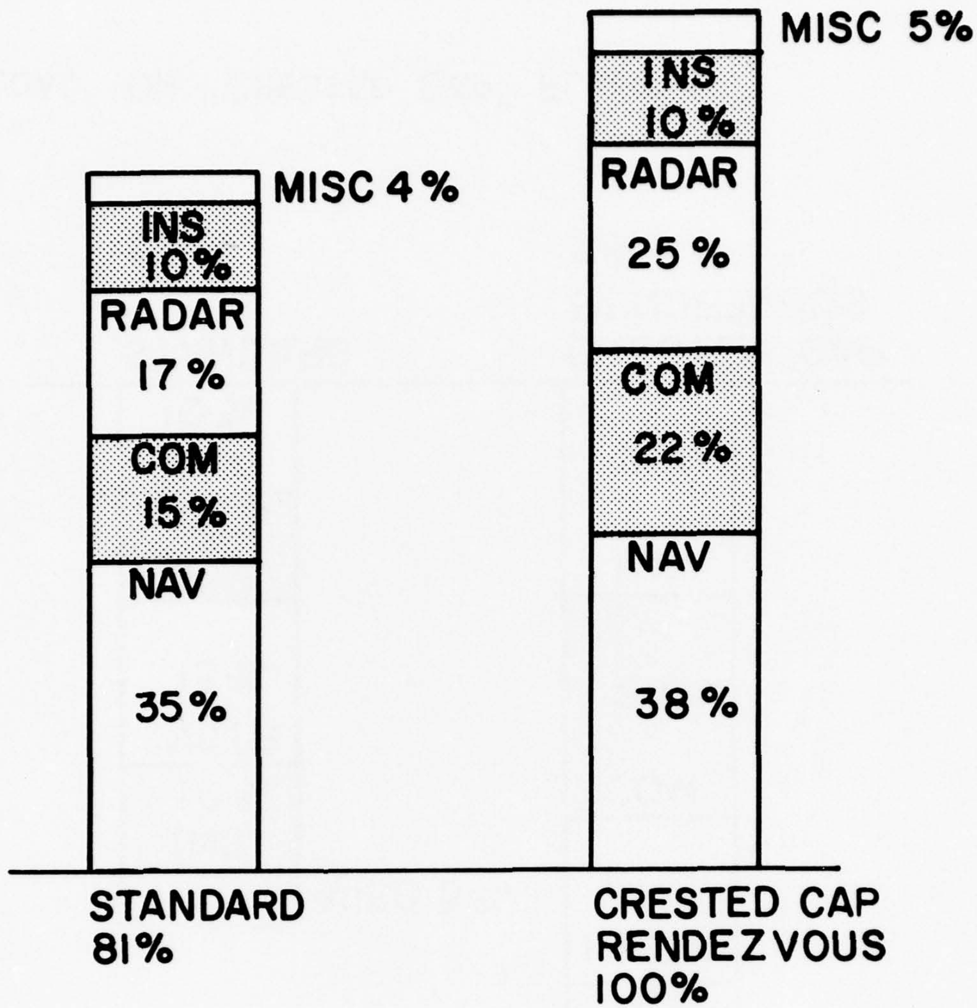
2. Questionnaire Data

Detailed responses to the questionnaire distributed after each flight are presented in the Appendix. A summary of these comments is presented below.



COFILOT WORKLOAD ON "CRESTED CAP" FLIGHT

FIGURE 5



FLIGHT SYSTEMS OPERATOR WORKLOAD ON "CRESTED CAP" FLIGHT

FIGURE 6

Problems were encountered by crews in the earlier flights in operating the INS but, as the flights progressed, these difficulties gradually disappeared. Most of these difficulties were in learning to use the "Mode 22" of the INS (to fly the refueling orbit). The FSO reported some difficulty in picking up receivers' beacons but this was largely due to equipment difficulties rather than lack of knowledge about the system. The most difficult area for the FSOs was learning to use the radar for Airborne Radar Directed Approaches (ARDA) but they became proficient in the later phase of the program. More initial training in this area may be required. As in GIANT CHANGE, there was not sufficient time for the crews to acquire enough knowledge about the more sophisticated uses of the INS.

When questioned about the feasibility of performing flying duties and navigating, the copilots who had flown in the GIANT CHANGE Program said the arrangement in GIANT BOOM was much easier than in GIANT CHANGE. The copilots felt that reprogramming the INS presented the most difficulty and, in some cases, would require the pilot to handle communications temporarily. The pilots in their response to this question stressed the need for thorough mission planning to avoid overloads during the mission. They also cited the need to have the pilot's communication monitored by the copilot or other crew member if the copilot is not available.

All crew members replied negatively to the question: Did you feel overloaded during any segment of the mission? The copilot and FSO reported periods where they were fully loaded but never overloaded. Table 3 shows the rendezvous task load division by crew position as reported in the questionnaires.

Question 7 shows that the relative importance of each piece of navigation equipment is a function of crew position. The Palletized Inertial Navigation System Horizontal Situation Indicator (PINS HSI) was most important to the aircraft commander in his tasks while the INS display was most important to the copilot and FSO. The HSI was second most important to the copilot while the radar was second for the FSO.

TABLE 3

RENDEZVOUS WORKLOAD DISTRIBUTION (SELF-REPORTED)

RENDEZVOUS TASK	P	CP	FSO
RADAR	1%	15%	41%
INS	26%	23%	38%
COMMUNICATION	21%	14%	20%
LOOKING OUTSIDE	34%	29%	0%
OTHER	19%	22%	1%

When questioned about the positioning of the navigation equipment added for the test program, the responses were negative in general (as they were in GIANT CHANGE). The HSI blocks forward out-of-the-window vision, and the INS interferes with the hydraulic switches and nosewheel steering. The positioning of the second (CP's) radar was also considered undesirable.

The crews felt additional training was required in the following areas: radar (pilot/copilot), Grid navigation (copilot/FSO), and ARDA (FSO).

All crew members felt the INS would improve procedures during refueling and recovery on an Emergency War Order (EWO) mission. Rendezvous were quicker and smoother because the tankers' positions were more accurate; the pilot's tasks and crosschecks for maintaining the rendezvous orbit were greatly simplified. The INS simplified the work required on mission changes and provides a self-contained fixing aid for recovery when no other aid is available (when overwater or TACAN/VOR is not usable). All crew members indicated extremely high confidence in successfully completing an EWO mission using the test system and displays.

Numerous detailed checklist changes, additions, and deletions are given in Questionnaire Item 14.

There was some difficulty reported on changing control times but these were reported in the earlier missions (this was not the case as the crews became proficient). The same was true of workload affecting safety of flight. Once crew coordination procedures were worked out, there were no overload problems encountered.

Finally, pilots reported "head in cockpit" time with PINS to average 10 to 19 percent higher over the total mission than with the standard KC-135 configuration. Copilots reported only a 10 percent increase in "head in cockpit" time over the total mission; however, they reported an average increase during the short mission change and way-point insertion periods of 40 percent.

SECTION IV
DISCUSSION

The results of this study indicate that the enlisted Flight System Operators performed very well and were able to accomplish all aspects of all missions as required. They were able to run the rendezvous across all missions particularly well. The use of the radar for weather avoidance was accomplished with no difficulties (in contrast to the difficulties encountered by the copilots in interpreting weather returns in GIANT CHANGE). This was, no doubt, due to the FSOs having received considerably more training in radar interpretation than the copilot had received in the earlier study. The FSO did have some difficulty in shooting ARDAs but this is considered a difficult task even for personnel experienced in radar procedures. In addition, the number of sorties flown by each FSO in this study is not deemed sufficient to develop a high level of proficiency in shooting ARDAs.

Initially, difficulties were encountered in using the FSO as conceptualized in the test plan. There was a strong tendency for the crews to employ the FSO in the same manner that navigators are currently used in the KC-135 refueling mission. In the first half of the study, the crew had to be constantly impressed with the fact that the copilot had prime responsibility for navigation while the FSO had responsibility for the radar function, rendezvous, and relief of the copilot's navigation duties when the copilot was in an overload situation. This confusion was partially because no detailed and formalized crew procedures using an FSO had been developed prior to the test. As the program proceeded, the crews did a good job of developing crew procedures and eventually developed excellent crew coordination and integration. If SAC does convert to use of an FSO, such formalized procedures will need to be specified.

In line with this observation, the authors also noted that the FSO's workload was probably higher than necessary on the standard

refueling mission. The 81 percent task load cited in the Results section reflects some self-imposed task loading such as performing extraneous navigation functions (using the radar to crosscheck the INS and taking radar fixes when not required.) This was due to the FSO's uncertainty about his function and to his practicing navigation in anticipation of the later polar flights. The authors feel that this artifact in the data inflated the task load figure approximately 20 percent so that the actual required workload on the standard mission would have been approximately 61 percent. In an operational situation with an experienced FSO, we feel that a realistic task load would be at the 61 percent level. The FSO task load on other portions of the test are considered accurate.

The addition of the FSO in this study reduced the copilot's task load approximately 40 - 60 percent depending on the type of mission. The additional crew member overcame all the unacceptable disadvantages encountered in the GIANT CHANGE Program. The copilot's workload was reduced to reasonable levels, no critical checklist items were omitted, and the concept of "see and avoid" was preserved. There were isolated instances of errors and some phases where the crews were fully loaded (but never overloaded). In short, the crew performance was dramatically changed from that observed in GIANT CHANGE. However, two observations that were similar were the requirement to have a better crew station equipment arrangement than that in the test aircraft, and the necessity for more time to perform preflight checks (due to the lengthy INS procedures and warm-up).

Since the enlisted FSOs performed so well, the question has been raised: Is it possible that a less experienced individual could, with adequate training, also perform the required tasks? Our answer is a qualified "yes." The qualifications are:

1. Much more extensive training will be required.

2. Very careful selection procedures will have to be followed so that candidates will show a high general aptitude as well as specific

capacities in the skills required. Probably, a selection test for this FSO career field should be developed.

3. Testing in selected squadrons should be conducted prior to operational implementation.

SECTION V

CONCLUSIONS

The results of this study definitely indicate that the use of an experienced enlisted FSO in conjunction with a copilot to perform the navigation function for refueling operations is feasible.

The task load figures show no overload situations nor any safety hazard.

The use of a less experienced FSO may be feasible but will require more extensive training, careful selection of candidate operators, and pre-implementation testing.

APPENDIX

QUESTIONNAIRE RESPONSES

NOTE: Responses listed here summarize common responses throughout the test program; a few very important single comments are also included.

2. Have you had any prior experience in the use of:

a. INS (Explain fully)?

P - No
P - Aircraft commander (A/C) for Giant Change
CP - CP for Giant Change
CP - 1 Giant Boom flight
O - No
O - CP on Giant Change
O - 1 US & 3 trans-Atlantic flight
O - 1 trans-Atlantic flight
F - Passenger on 2 Giant Change flights; 1 Giant Boom flight
F - 1 Giant Boom flight

b. Radar (Explain fully)?

P - No
P - EC-47 weather (wx) radar
CP - CP for Giant Change
CP - No
O - No
O - EC-47 wx radar, Primary CP for Giant Change
O - Slight use of wx radar
O - EC-121 wx radar
O - Some at KC-135 CP position
F - Radar Systems Operator Course at Castle AFB; 1 orientation/training flight at Pease AFB
F - Radar Systems Operator Course at Castle AFB; 1 orientation/training flight at Pease AFB

3. Mission Data: Summarized in main body of report

4. Did you have any difficulties while operating or using the following equipment?

a. INS:

P - Minor difficulties on initial flights in programming & "22 Mode" because of unfamiliarity with INS displays, locations, and operating procedures

CP - Slowness & minor difficulties on initial flights

O - On initial flights, crew didn't use INS to fullest extent; crew was confused at some points on INS operation and needed time to confirm their findings; FSO was confused on "22 Mode"

F - Coordinating with pilots slowed down the preflight; FSO has no checklist for INS's 22 Mode; minor difficulty entering & exiting 22 Mode

b. Radar:

(1) Positioning

P - These are CP & FSO functions

CP - Coordinated with FSO to understand radar settings and changes

F - Fixes on initial flights were 2-4 miles off; Forgot to adjust variation control; Unable to obtain radar fix for 30 minutes around North Magnetic Pole

(2) Rendezvous (Rz)

CP - No, FSO set it up & it worked perfectly; Repeated difficulty seeing receiver's radar beacon

O - FSO could not pick up receiver's beacon until 30 miles away

F - Often, beacons were not painted and ADFs did not work; Differential INS distances (receiver's reading minus tanker's reading) used to perform Rz; Overrun procedures used once because tankers didn't turn until receivers were sighted visually

(3) Station Keeping:

CP - Excellent position maintained by FSO

O - FSO monitored cell position fairly well

(4) WX Avoidance:

All - No significant weather encountered

(5) Other (Explain):

F - Difficulty performing ARDA

5. How do you feel about performing normal pilot duties while concurrently performing the navigation functions?

P - Initial flights suffered from having to develop an effective crew coordination and division of labor for the new systems; If A/C forces crew to spend enough time in mission planning, many inflight mission difficulties are avoided; Normal & safe if FSO directs the Rz and backs up the CP on mission navigation; Other crew members need to back up the pilots on headings, altitudes and turn directions during mission changes (pilot turned wrong way); System forces pilots to maintain much better position awareness while providing more time for both navigating and flying.

CP - Much easier to navigate with PINS (FSO monitors its accuracy); Pacing was easy except when reprogramming INS with new waypoints (normal or mission change)--at that point, pilot must assume some of CP workload (e.g., radio calls)

O - Slight workload increase: 20-30% more than with a navigator, and 10-20% more than piloting from TACAN to TACAN

6. Were there segments of the mission where you felt overloaded (pressed for time)?

P - Generally, no; During Rz with another aircraft behind us in cell, I felt I wasn't sufficiently monitoring the receiver's progress to ARCP

CP - I was fully loaded during INS waypoint-insertion--if any unusual problems developed, I would have been overloaded; Fully loaded (not overloaded) during mission changes because of unfamiliarity with navigation in general (not INS)

O - Generally, none observed

F - No

7. Instruments. Rate the instruments listed below in the overall importance during this mission. (1 = most important, 2 = next most important, etc.)

	P	CP	O	F
HSI (PINS)	1	2	1.5	/
INS	2	1	1.5	1
Radar	3	3	3	2
Doppler	4	4	4	3
Other (TACAN)	/	/	5	/

8. During rendezvous, how much time was devoted to:

	P	CP	F
a. Using the radar	1%	15%	41%
b. Looking outside aircraft?	34%	29%	0%
c. Using the INS?	26%	23%	38%
d. Using the radio?	21%	14%	20%
e. Using other equipment (ADF, Air-Air TACAN, Checklists)?	19%	22%	1%

9. Comment on the Location and visibility of:

a. INS:

P - Location fine but control head should be flush with other equipment panels; Location interferes with hydraulic switch and nose-wheel steering

CP - Computer Display Unit (CDU) would be more convenient in the fuel panel area; Mode Selector Unit (MSU) present location in side panel is better than its Giant Change location; CDU is awkward to program "sideways" -- would be much better for key pressing and to reduce sun glare if it were positioned more toward the instrument panel on a 45° angle to the pilots

O - Should be forward more toward instrument panel; INS "Alert" light should be on HSI in normal visual crosscheck area for pilot rather than down by his knee

F - Good

b. HSI:

P - Blocks pilot's view from 12 o'clock to 1 o'clock positions inflight and when taxiing;Instruments should be incorporated into pilot's and copilot's instrument panels; Extremely bad due to glare and blocking outside vision

CP - Usable by both pilots though location causes parallax reading error; Should have one for each pilot centered in front of him; Creates blind spot & hard to read accurately

O - Each pilot should have his own display; Incorporate into FD-109; Gives small blind spot.

F - Good

c. Radar:

P - CP's Radarscope should be in central instrument panel reducing sun glare and readable by both pilots

CP - Poor location and visibility; It's physically, very hard to bend over and use the scope; Glare on the scope face makes reading difficult; Radarscope is so low and hood so short that sun's glare often spills in

O - Radar scope location is very poor for daytime & aircraft commander's use

F - Excellent (At Navigator's station)

d. Other (Explain):

P - Pilot's oxygen panel location is inadequate since the "Emergency" toggle is often depressed when replacing helmet (need better location or different regulator); If the "IFF Ident." switch had a repeater for the pilot, he could reduce coordination problems and some of the FSO's workload during peak problem periods.

10. Based on the results of the mission, what additional mission planning items would you accomplish for your next mission?

P - Navigational techniques concerning "mission change" and "alternate (second) rendezvous" procedures; Better crew coordination between FSO and CP (especially on navigation responsibilities and necessity of comparing results)

CP - Have inflight INS reprogramming done by CP and FSO (leave P out of this in order to fly aircraft and handle radios); Better coordination between pilots & FSO over procedures for handling mission changes, route changes, and navigation when the INS's fail; More work at understanding Grid reference system for polar flights; More on weather avoidance and "fighter rendezvous" procedures for Crested Cap

O - Replan alternate Rz more thoroughly; Use boom operator to relieve high crew workloads (e.g., comm, fuel log)

F - More detailed discussion of the crew's division of labor to accomplish alternate Rz and mission changes; Better planning for entering Grid and doing Grid fixing on polar flights

11. Do you feel additional training is desirable and, if so, in what areas?

P - Many repeated comments on the need for Radar training, Grid training, and basic navigation refreshers for both pilots; Grid for FSO; Radar training using scope photographs

CP - FSO and CP need more training in basic manual DR, radar fixing, Grid, and radar Rz procedures (especially with fighters); On best crew coordination for performing tasks/activities inflight

O - Yes, On inflight mission changes and loading INS properly/rapidly

F - On Airborne Radar-Directed Approach (ARDA); Grid entry, Grid exit, and Grid fixing on radar

12. Do you feel the INS would improve procedures during refueling and recovery on an EWO mission? Explain:

P - Definitely yes, due to the much greater accuracy of the INS; Refueling would be quicker because tanker's position is more accurate; Yes, mission would be overwater and recovery bases would be hard to find otherwise

CP - Yes, definitely -- greatly simplifies the pilot's task and crosscheck for maintaining the orbit; It simplifies mission changes and improves position awareness; It definitely improves recovery chances because TACAN/VOR would probably not be usable

O - Yes, it would ease the workload and improve the quality of navigation on unscheduled Air Refuelings (A/R); Ultimate equipment to satisfy total self-sufficiency of aircraft navigation; Rz are more accurate and it helps fuel conservation because you stay on course much better (fuel figures based upon on-course nav); You can give better fixes to your receivers

F - Yes, it provides the flexibility to proceed to any ARCP easily and accurately; It gives instant time and distance figures for maintaining the proper refueling orbit

13. Given the present system (INS) and displays, rate how confident you would be in successfully completing an EWO mission.

7	6	5	4	3	2	1
-	-	-	-	-	-	-
Very unsure						Very confident

P - 1.25 average (1.0 after 3rd flight)

CP - 1.125 average

O - 1.0 median

F - 1.8 average (1.0 after 3rd flight)

14. Do you have any recommended checklist changes/additions/deletions?

P - In Preparation for Contact, Include: "INS-22 Mode"; In Before Starting Engines, the first step should be: "INS - Nav Mode"; For the INS checklist, move the "INS - Test" to a point after the insertion of present position

CP - Eliminate amplified explanations from checklists; Develop a checklist for inflight mission changes that lists everything that needs to get done and by whom

O - Crew should put INS in Standby during preflight prior to aligning; Eliminate various explanations between actual steps; Rework checklist to put Boom Operator to better use

F - In Start Engines, change Item 1 to "INS-NAV" (i.e., insure both pilots' INS's are in NAV prior to engine start); In Preparation for Contact, add new Item 5A: "INS - 22 Mode" (i.e., insure one INS is in 22 - Mode before ARCP); In FSO checklist, Interior Inspection-Power On, change Item 4 from "INS-Align" to INS-Checked" with amplification to read and check Present Position and Waypoints 1-9 in both INS 1 & INS 2; Change Item 5 of previous checklist from "INS - Set" to "INS - 22 Mode Checked" with amplification to read and check INS 1 & 2 in the 22 Mode for ARCP coordinates and receiver's inbound true track

15. Would the INS provide an additional safety factor for penetration and landing with external nav aids available?

P - Yes, it assures you have the proper airport & it gives GS and Drift for instrument approaches; Good back-up to maintain course and avoid high obstacles/terrain

CP - Some "No", Most "Yes"; Additional crosscheck on runway's location compared to aircraft's position; Gives pilots better position awareness and allows easier planning ahead of time; Gives good backup to monitor FSO's ARDA

O - Yes, Groundspeed function could give backup timing for ILS Approach; Drift function useful in all modes; Slight safety factor as long as it doesn't cause an oversight of normal duties or detract from the primary approach aids

F - Yes, it permits precise entry into landing patterns

16. Was any weather avoidance necessary during this mission? If so, how did it affect pacing, workload, crew coordination? Were you able to effectively avoid the weather?

ASD NOTE: Only two of 12 evaluation flights encountered weather (on one additional Wx flight, FSO's inoperative radar forced us to relinquish cell lead)

P - Adequate, no effect on mission

CP - Minor alterations by CP & FSO to avoid thunderstorms

O - Easy, quick & accurate

F - Gave no problem; DR used to position aircraft and then radar used to fix after clear of weather

17. Were control times revised inflight? If so, how did it affect pacing, workloads, etc?

P - Crews handled mission changes (with second A/R's and new control times) smoothly and with good pacing

CP - Inflight changes increase CP's workload but easily handled when pilot assumes part of CP's workload (e.g., radios); Pacing affected by overload & wait for FSO to pass 2nd A/R ARCP coordinates from Flight Publications Planning Document.

O - Weak area of flight -- calls for better coordination between FSO and pilots; When new A/R was added, CP & FSO spent 20 minutes working entirely on revised routing to exclusion of all other tasks -- Pilot spent 1/3 of time controlling aircraft and comm radios, 1/3 INS navigating, 1/3 coordinating changes; Pacing increased -- workload doubled

F - Slow in providing info on initial flights because of lack of confidence in answers; Pacing good on later flights

18. Do you feel there were any segments of the mission where safety of flight could be jeopardized due to increased workloads?

P - Generally, no (once pilots are familiar with programming the INS); During problem situations (e.g., mission changes), fuel monitoring could be overlooked unless boom operator is made responsible for it during that period

CP - Yes, inflight waypoint loading by <u>both</u> pilots is dangerous (not enough scanning & flying aircraft)--INS should be done by CP and FSO; Only when the pilot gets too involved in the CP's inflight loading of waypoints

O - At night, INS control panel lighting gives off too much light for its importance ... not tuned to KC-135 system

F - Generally, no; Only when pilots do not scan outside aircraft during mission changes

19. What would you do if your INS malfunctioned during overwater or polar flight?

P - Most responses were to use Dead Reckoning (DR) with available radar fixing to confirm DR;

CP - Carry DR's from last known position (with flight planned headings, airspeeds & winds) and use radar and other aids available to navigate (directing FSO to fix with radar also)

O - 1: Use operable INS, 2: DR while FSO provides available radar fixes, 3: Use TACAN/VOR whenever possible; When INS failure was simulated on a polar flight, it didn't seem to change the crew's work rate

F - DR from last known position to land or within range of TACAN/VOR

20. List any degradation in the following areas as a result of increased workloads:

a. Preflight:

CP - Slower due to being with new crew learning INS procedures; Preflight requires 10-15 minutes extra time in order to program the INS

O - Extra time to load the INS physically in preflight has to be planned for

b. Taxi/Takeoff: None

c. Climb:

O - Crew's inexperience with INS programming caused some loss of attention to cell position

d. Cruise:

P - Slight on initial flights due to crew's inexperience with INS

CP - With simulated INS failure, navigation by DR and radar is extremely time-consuming; If INS is working, workload is simplified -- if INS is out, there is a partial loss of CP for pilot duties since he must do radar navigating to check FSO; Multiple INS displays at all stations (not just nav's) would increase crew's confidence and task performance flexibility

O - Fuel panel management overlooked at times

e. Pre A/R:

P - Generally, no; Because we were leading the cell, the division of labor became tight and lead techniques suffered some -- also true during Rz and some of time on nav leg

CP - Slight increase in workload when CP monitors the Rz on radar; Rz easier with INS; Slight increase in workload due to setting up 22-Mode of PINS

O - (On the second evaluation flight) the orbit, entry & Rz were confused due to INS inexpertise

f. A/R: Generally, none

g. Post A/R: None

h. Penetration:

CP - PINS provides additional backup to existing nav aids here; PINS provides good info for planning the descent & decreases mental workloads

i. Approach Phase:

CP - PINS provides additional backup to existing nav aids here

F - FSO needs practice in ARDA's

21. Increased workloads are assumed to increase "head in the cockpit" time and, thereby, decrease the pilots' ability to "see and avoid." Estimate the approximate increase in time required as a result of the increased tasks:

P - 10 to 19% increase over total mission; Increases: Preflight - 10 to 19%; Taxi/TO — 5%; Climb - 6 to 9%; Cruise - 10 to 19%; Pre A/R - 20%; A/R - 10 to 19%; Post A/R - 10%; Pntrn - 6 to 9%; Approach - 5%

CP - About 10% increase over total mission; Increases: Preflight - 20%; Taxi/TO - 5%; Climb - 6 to 9%; Cruise (ONLY during mission changes and waypoint insertions) - 40%; Pre A/R - 30%; A/R - 6 to 9%; Post A/R - 10%; Pntrn - 10 to 19%; Approach - 5%

O - 6 to 9% increase over total mission; Increases: Preflight - 20 to 29%; Taxi/To - 5%; Climb - 5%; Cruise - 5% for Pilot, 40 to 49% for CP during mission change or waypoint insertion; Pre A/R - 6 to 9% for P, 5% for CP; A/R - 10 to 19%; Post A/R - 10 to 19%; Pntrn - 5%; Approach - 5%

F - None reported (due to his position at nav station)

22. Address any other areas you feel are applicable to the purposes of this test program:

P - "See & Avoid" suffers most during inflight INS reprogramming by both pilots -- better solution is for pilots to coordinate the waypoints to be loaded & have CP do loading with FSO monitoring; After 3 flights, we solved the coordination problems: P is responsible for flying the aircraft & supervising navigation needs of the flight, CP coordinates all nav changes with pilot & compares solutions with FSO, FSO checks all INS programming, conducts A/R (pilots back him up with alternate means), & performs

wx avoidance; A flushable toilet for the KC-135 is another highly desirable innovation that would improve human performance and safety inflight -- its lack directly interfered with performance on these missions (especially on the 8 and 11 hour missions); This PINS test equipment allows a very effective means of completing the strategic air refueling mission

CP - Careful on-ground coordination required to insure all crew members have the same flight plan points designated with the same waypoint numbers; PINS system purchased should have HSI able to operate off either INS (P's or CP's) -- with P out of seat and CP flying, CP cannot reach the waypoint change keys on the P's INS ... therefore, he cannot use the HSI to fly the aircraft after making the course change to go to a new waypoint; During mission changes, the first task to be dropped from priority is P's attention to fuel burn sequence -- best solution is to transfer this responsibility to Boom Operator (not FSO) during mission changes

O - To get accurate view of difference an INS makes in "Head in Cockpit" time, you should fly a normal mission (with recorders) identical to one with INS for comparison; This crew is much above average and results may reflect their superior collective abilities rather than INS; Evident that P & CP are very concerned with INS and doing much double work just due to novelty of the test situation; CP's radar <u>must</u> be improved if he is to assume greater radar navigation responsibility-- tuning the radar for best picture at the nav's station did not give the CP's a well-tuned picture since the two scope presentations appeared not to be calibrated with each other

F - FSO needs a condensed checklist for checking 22 Mode of INS during preflight

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